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ABSTRACT

This document outlines the present state of development in mass restoration of library and archive materials and relates it to the economic, technical, and aesthetic aspects of various conservation and restoration methods, and discusses their implications for the formation of preservation policies in libraries. Ill effects to library materials caused by mechanical, biological, and chemical damage are discussed, and the current situation in libraries is briefly described. The following methods of conservation are then explored: (1) the diethylzinc (DEZ) method, which is not yet ready for use; (2) the Wei T'o non-acqueous book deacidification system method which was invented and developed in Canada; (3) the deacidification methods of the Bibliotheque Nationale (the French National Library in Paris), which are similar to the Wei T'o methods; (4) the methods being developed by the British National Library in London; (5) the Viennese method, an aqueous immersion treatment for newsprint that simultaneously neutralizes and strengthens the paper; and (6) several additional experimental methods. Four methods of restoration currently in use are also described: the wet treatment; leafcasting; the paper-splitting process; and the lamination process. (9 references) (SD)

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Study on mass conservation techniques for treatment of library and archives material

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General Information Programme and UNISIST

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STUDY ON MASS CONSERVATION TECHNIQUES

FOR TREATMENT OF LIBRARY AND ARCHIVES MATERIAL

prepared by the Regional Centre of the IFLA Core Programme FAC,
Deutsche Bücherei Leipzig, GDR

Edited by Wolfgang Wächter under the supervision of Helmuth Rötzsch

General Information Programme and UNISIST

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PREFACE

In order to assist in meeting the needs of Member States, particularly developing countries, in the specialized areas of Archives Administration and Records Management, the Division of the General Information Programme has developed a long-term Records and Archives Management Programme - RAMP.

The basic elements of RAMP reflect and contribute to the overall themes of the General Information Programme. RAMP thus includes projects, studies and other activities intented to :

- develop standards, rules, methods and other normative tools for the processing and transfer of specialized information and the creation of compatible information systems ;

- enable developing countries to set up their own data bases and to have access to those now in existence throughout the world, so as to increase the exchange and flow of information through the application of modern technologies ;

- promote the development of specialized regional information networks ;

- contribute to the harmonious development of compatible international information services and systems ;

- set up national information systems and improve the various components of these systems ;

- formulate development policies and plans in this field ;

- train information specialists and users and develop the national and regional potential for education and training in the information sciences, library science and archives administration.

This study aims at describing the state of development in mass restoration and preservation methods whatever the medium may be; it highlights the various aspects, technical, economic, etc. and the importance of the role accorded to preservation in library and archives policy.

Relying among other things on the results of the world survey carried out in 1986 by Unesco, IFLA and ICA among libraries and archives concerning preservation, the study examines step by step the different kinds of damage (mechanical, biological, chemical) occurring on library materials and their causes, the conditions in which the libraries are found, and methods of restoration. A short bibliography completes the work.

Comments and suggestions regarding the study are welcomed and should be addressed to the Division of the General Information Programme, UNESCO, 7, Place de Fontenoy, 75700 PARIS, France. Other studies prepared as part of the RAMP programme may also be obtained at the same address.

IFLA STUDY

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1. Introduction

In the last few years it has been established in many specialist publications that it is necessary to develop mass preservation and restoration processes in order to preserve the contents of libraries and archives. In view of the serious situation in libraries and archives, various efforts have been made internationally by chemists, curators and restorers to find adequate ways of preserving endangered cultural assets.

The following is an attempt at outlining the present state of development in mass restoration and preservation methods and to relate it to the economic, technical and aesthetic aspects. Libraries, as centres of science and culture, fulfill varying and specific tasks. At the same time, they serve the purpose of collecting, developing and storing literary documents. The most important basic material of the library collections is still the paper - a material composed more or less solely of cellulose. In the last few years the reproduction of recorded knowledge onto polymer materials, so-called microforms, has increasingly spread which consequently supplements the classical form of paper. Irrespective of their basic material, collected items in libraries are liable to undergo certain changes, which particularly in long-term storage can have a negative effect on them. These processes, which are governed by law can be summarized under the term of "ageing". Every kind of material undergoes specific changes, but the ageing process of paper is the result of chemical reactions, whose velocity depends on varying "interior" and"exterior" factors. Consequently, this means that the existence and the storage of library materials is inextricably linked methods of pre-

servation and restoration. It would be senseless investing, year after year, in a great deal of additional material without attending to the further usage of the library material. Preservation and conservation therefore play an increasingly important role in library policy.
We bring together under the term "preservation" all the steps and necessary procedures which influence the external factors of ageing in the sense of prolonging the life of the library materials. An important factor which has some influence are the storage conditions - temperature, humidity and light. Hygienic aspects in the stockroom such as cleanliness, well-planned ordering of the materials in functional, well-built shelves, an examination of the microbiological and insecticidal environment, steps twoards the reduction of air pollution etc., are further necessities in conservation.
Another important conservational task of librarians is the organisation of its use. The most important points here are the frequency of use, specialist use of books by readers, the frequency of duplication and not least the question of transportation from stockroom and back to the borrowers through the library workers.
In order to achieve these steps in conservation it is necessary to train employees in conservation. This does not mean simply the restorers or curators. To an increasing degree there is a growing need for librarians and stockroom personnel to have a basic knowledge of conservation, so that the optimum requirements for the preservation of library materials can be guarenteed.
We collect together under the term "preservation" all the steps which are concerned with the elimination of damage

to library books. The main aim is to influence interior factors of ageing in the sense of prolonging the lifespan and eliminating visible damage, so that the use of the materials is guarenteed.
Quite a considerable part of the work process consists, for example, of analyzing the damage, of deacidifying and impregnating an alkaline reserve, of partly or wholly strengthening, of reconstitution of covers, plus the documentation of all restoration procedures.
A basic principle which dictates whether restoration work will be executed qualitatively and quantitavely well is the availability of specific basic materials and their actual type will be defined by the main area of damage in the library. Furthermore, well-trained specialists, who are able to fulfill the needs of the library are indispensable.

2. Damage to library material and its causes

In order to be able to ascertain the various different kinds of damage to library materials and to be able to carry out suitable restoration work, a system fo classifying the damage along with their causes was necessary.
In the following pages all types of damage which actually occur in practice have been classified.

I. Mechanical damage

Under this heading we class all the kinds of damage which manifest themselves "physically". This kind of damage is characteristically found restricted to a particular area and slight

damage of the "grey zone"type is uncommon here. This kind of damage always occurs when the destructive forces put too great a strain on the inherent strength of the material constitution. Causes of mechanical damage can be due to:
a) the way the book is made
b) improper use of the book
c) violent influences from outside
For example, if a book falls from the book trolley during transportation, this could cause the book-cover from being torn from the book block. Very frequent turning of the books' pages can easily lead to damage.

II. Biological damage

This is the collective name for all kinds of damage caused by various different living organisms. Biological damage differs in the way it occurs and in the effects from the attack.
Biological damage is caused by an attack of a) micro-organisms
Bacteria: cause mildew marks restricted to certain patches (depending on the pathogen, changes in colour may also be registered) along with the enzymatic decomposition of the material substance.
Moulds: are, in practice, the most common causes of damage (up until now over 300 different species have been proved to exist on books and paper. The damage differs in colour over large areas on the most diverse kinds of materials - the mould causes differing degrees of enzymatic decomposition , which has the character of chemical damage.
Micro-organisms are omnipresent on earth. Particularly the permanent parts of them, the spores, can be detected nearly everywhere, therefore logically also on library material.
If favourable conditions such as sufficient temperature, humidity and a culture medium coincide, then a development and propogation of the microbes along with an on-going decomposition of the culture medium begins, the medium being in our

case materials containing cellulose. Apart from in the event of a catastrophe such as flooding, water damage from extinguishers after a fire or a leaking or burst water or heating pipe, a sufficient amount of water can be present through unfavourable temperatures and humidity in stockrooms. As paper is a hygroscopic material, it is possible to detect sufficient water to germinate spores (even with adherence to recommended climatic conditions). Microbes are capable, in an extreme case, of breaking down the cellulose to glucose during one life cycle. These chemical changes lead to serious types of damage with irreversible changes in the material.

b) Insects

According to biological species they cause typical, different-shaped bite-marks belonging to mechanical damage. Virtually all materials of paper or book structure are open to insect attacks.

Insecticidal pests are able to adapt themselves quickly to changes in their environment. This characteristic accounts for them being so widespread and for their infestations being constantly in new surroundings. Insecticidal pests find a more favourable environment in closed rooms inhabited by humans than in the natural world. As they are "parasites of civilisation", they find protection from their natural enemies, more favourable climatic conditions and better basic food supply. The incidence of pests in collections and stockrooms depends both on different climatic and geographic conditions (sub-tropical regions offer a more favourable environment) and on actual ecological conditions. The structural state of the building, the microclimate, the culture substratum, the lighting conditions, the state of order and cleanliness all

have a considerable influence on whether development and multiplication can occur, in the form of active migration (by penetration of insecticidal pests from outside, for example, during times of swarming, or in the form of passive migration through infected books or packaging. The holometabolic insects are the most important group of all the book pests (whose development leads from egg to larva and pupa to fully-grown insect or imago). Damage (such as shavings, bore-holes etc.) are not always sufficient evidence to identify the kind of pest. The discovery of new bore-holes or areas which have been eaten away, larva shells, pupa skins or cacoons should be good enough reasons to take action.

c) rodents.

Rats and mice are typical examples of harmful rodents which do mechanical damage particularly to the exterior parts of library material which can be recognized through traces of gnaw and bite-marks. Structural deficiencies in cellar and roof stockrooms can be held responsible for their penetration. If materials are stored in stockrooms which are seldom frequented or hardly checked, then it is fairly likely that damage will occur by rodents.

III. Chemical damage

This group includes all types of damage which in the widest sense is caused by chemical reactions and whose causes are

a) Reactions which are long-term processes of a natural character,

b) Reactions which are accelerated by components prone to reaction,

c) Reactions caused by substances which penetrate from outside.

Irreversible changes to the material structure are common to all kinds of chemical damage. We can only name clear manifestations of this in very few cases. The different categories

overlap one another and accumulate.
The restorer comes across chemical damage belonging to this category most often on original material.The treatment of this sort of damage demands a great deal of skill and ability on his part.
The ageing process of paper is the result of on-going chemical processes. How fast this actually happens depends on different factors, although an exhaustive scientific account is still not possible with our present level of knowledge. A list of all factors involved which are already known to us, and an exact understanding of the way they react together is necessary in order to explain the process of ageing. Cellulose, being the basic element, forms the main element in the plant cell walls and is the most commonly occurring carbohydrate in the world of nature.
When pure cellulose is heated in correspondence with the values from the calculated molecular weight, an elementary analysis yields the formular $(C_6H_{10}O_5)$.
Cellulose is a colourless substance which is not soluble in
water or in most other organic solvents.
Large amounts of glucose residue are connected by ß-glucosidic I.4 oxygen bonds of long chains. In the macro-molecules the group $(C_6H_{10}O_5)$ repeats itself many times. The n after the bracket indicates the amount of links in the chain.
The degree of polymerisation (polymerisation: the joining together of similar smaller molecules to form macro-molecules and the size of the molecule is identical. The average degree of polymerisation (ALP) shows how many links $C_6H_{10}O_5$ there are in the cellulose molecule.
The production of cellulose fibres as the basic material for

making paper was, for centuries, predominantly a physical process. Flax, linen, ramie, cotton and other plant fibres consist of more or less pure cellulose. Flax fibres contain between 0.5 - 2.0% lignin according to provenance. The cellulose fibres are won either directly from the plants or indirectly via textile fabric through mechanical separation. If need be, the cellulose fibres then underwent alkaline treatment, but remained to a large extent in its natural form. By the end of the 19th century sweeping changes had taken place. The acquisition of cellulose fibre from wood and the process of chemical splitting altered the raw material base used in paper production, which also comprised considerable technical changes in comparison to the usual procedure of production up to that time.

When paper ages, the polysaccharidic elements of the fibre walls undergo negative changes both mechanically and optically. A breakdown of the polysaccharide (cellulose and hemicellulose) groups, together with an increase in the carbonyl and hydroxyl groups causes a decrease in the folding endurance. Research relating to this showed that when new paper is folded, the bonds between the fibres loosened, while the folding of old paper lead to breaks in the fibres.

The carbonyl groups, being the most reactive, have, along with the results of the oxydative changes, an effect on the reactivity of neighbouring groups (for example, the breakdown of of the ß-glucosidic bonds) and are decisively important in the formation of chromophores (responsible for yellowing). The breakdown of cellulose by acids leads, apart from an attack by the H-ions on the ß-glucosidic bonds, also to a rupture in the periodically established flaws which are arranged in levels and restrict defined elements of fibre.

In this way, ruptures occur across the fibre wall, the ALP sinks and the polymer-homologous hydrocellulose comes into being.The characteristics of hydrocellulose are dependent on the weight of the molecule and, in fact, as the breakdown goes on,the alkaline solubility and reactivity increase but the strength decreases. The ALP quantitiy to be measured and the alkaline solubility give a great deal of information on the state and strength of the cellulose.They are a way of measuring the damage to the fibres. The acid-hydrolytic breakdown can be expected in all paper which has been made in an acid medium. The oxydation of the cellulose into oxycelluloseoccurs particularly easily during the bleaching of the cellulose if this takes place in an acid medium or at too high a temperature. Oxycellulose, whose fibres are superficially attacked, possesses a reduced amount of strength through the formation of carboxyl groups and the oxidation of secondary hydroxyl groups into dialdehyde cellulose. Evidence of this is usually tested using Fehling's solution on the cellulose, whereby a higher reading denotes a worse quality.

A further considerable fact affecting the ageing of cellulose is the refining of the half stuff.

During refining the inner structure of the fibre wall is loosened resulting in it splitting up into segmented elements even more, through which water can more easily penetrate, therefore making the fibres more flexible and malleable. Furthermore,the surface of the fibres become fibrillated, which greatly enlarges the bondable surface and improves the bonds between the fibres. The breakdown of the strength-bearing polysaccharide is accelerated by this loosening of

the structure and the polymerization level of the breakdown products decreases.

The greater initial strength of the paper aimed at in the first milling or refining is no guarentee for its durability. The substances responsible for the yellowing in bleached cellulose are low molecular polysaccharide by-products with a high concentration of carbonyl and carboxyl. The formation of chromophore groups is very much assisted by the mechanical effects of the milling.

The breakdown of cellulose and hemicellulose by microbial enzymes produces a multicomponent system. Many cellulotically active micro-organisms synthesize cellulase, which converts the substratum of the paper into glucose. Three combined elements in an enzyme complex are necessary for this. C_I-cellulase, C_X-cellulase and ß-glucosidase have been detected in trichoderma viride myrothecium verucaria culture mediums, in different aspergills and in other fungae and bacteria. Only in unison are these three enzymes capable of breaking down cellulose to glucose.

C_I attacks native cellulose, leading to a loosening of the bonds, which through hydration of the substratum contributes to further water absorption and the densely-joined chains are driven apart. C_X-cellulose works in a hydrolytic way and attacks amorphous cellulose and cellulose derivatives. ß-glucosidase acts on cellobiose (a structural element of cellulose) and on other glucose ß-dimers.

If filter-paper is used as a culture substratum, the cellulase of 6 aspergillus species will cause a decomposition of 55-88% to take place. Ten kinds of wood-fungi caused a decomposition of between 3-91%, four sorts of penicillium up to 61% decomposition, four types of trichoderma up to 53% decomposition. Leaving the microbes enzymatic system of

decomposition, the fact that the organic acids are capable of synthesizing must also certainly have a destructive effect. The aspergillus species are used for example on an industrial scale in the production of citric and gluconic acid.
These chemical processes of decomposition must be seen altogether in connection with the external factors of long-term storage. Temperature, humidity, light and air pollution have a considerable influence on the speed of ageing in cellulose products. Temperature and humidity, in their dependence on nature, are primary sources of influence on hygroscopic materials such as paper, leather and parchment. It is plausible that chemical processes are more likely to increase under higher temperatures and humidity. 25°C and 32°C seem to be critical temperatures at which the ageing of paper speeds up progressively. At higher temperatures the water molecules in the paper are present in an isolated form and are more active, whereas at low temperatures the H_2O molecules remain in concentrations which are inert to reaction.
Humidity is determined by the amount of steam in the air. The relative humidity is the ratio of absolute humidity to the prevailing temperature possible at saturation point - that is maximum humidity. This information can be gained by reading the hygrometer in per cent.
The degree of saturation can be ascertained by the data on the table - for example

for	15°C	12.8 g/m^3 air
	20°C	17.3 g/m^3 air
	25°C	23.0 g/m^3 air.

The absolute air humidity rises with the constant relative air humidity when the temperature rises by nearly twice as

much again from 15°C to 25°C, that is, from 7.68 g/m^3 to 13.8 g/m^3. These ratios are of particular interest in regard to the micro-climate in the stockrooms or exhibition rooms, and they should be taken into consideration when decisions on controlling air humidity are made. Particularly hygroscopic material such as parchment reacts very vigorously to these differences and can in extreme cases cause great damage. The ability to absorb water from the ambient air differs considerably both within the material group (for example paper) as well as between the different material groups themselves. The negative influence of air pollution in the form of sulphur dioxide, nitric oxide and chlorides on the lifespan of objects is particularly well illustrated by the weathering of stone monuments. The effect of aggressive atmospheric elements on books and paper has an intensified effect on the process of decomposition. The destructive effect of ultraviolet rays on the molecular chains in paper is particularly serious in the wave-lengths between 300 - 500 nanometers. The greatest proportion of these ultraviolet rays are found in sun and daylight. The photochemical reactions can on the one hand lead to paper-yellowing, on the other hand to the bleaching out of inks and pigments. The energy which accumulates due to the ultraviolet rays leads in differing degrees to the breakdown of chemical bonds in the material which leads to the occurrence of free radicals. Their reaction to oxygen starts off a chain reaction, which in the end can lead to the total destruction of the paper (photolysis).

It should also be mentioned that the diffusion of harmful substances through direct contact of the paper with unsuit-

able materials is also possible. Pass-partout materials, glues, protective foils etc. involves the risk of spreading harmful substances. It may also be possible that products such as softening agents or also acidic by-products of the contact materials can cause damage.
Internal and external causes of paper-ageing, or to be more general, of the ageing of historical materials, can, in the job of the restorer mostly be registered as conclusive phenomena, which, apart from the physical and chemical changes in the material, also lead to aesthetic changes in the object.

3. The situation in the libraries

Nowadays it is no longer questioned that the decay of library materials is an international problem. Differing attitudes on the extent of the damage do not contribute much to solving the problem. The collections in our libraries are just as much a part of our cultural heritage as historical monuments, paintings and archaeological discoveries. In contrast to them, books are used daily, this means that they must be mechanically and functionally in order. If the quality of the paper or the book-binding materials worsen, then the lifespan of the book will be shortened accordingly.

More than 90% of the books stored in our libraries and archives originate from the 19th and 20th centuries. The famous William J. Barrow Research Laboratory discovered in a comprehensive study on the contents of modern libraries that more than 50% of the books printed between 1900 and 1945 will no longer exist by zhe year 2000.

This basic hypothesis was confirmed by research carried out by the British Library and the Bibliothèque Nationale. The following unanimous results were arrived at on the constant ageing process of book paper:

About 97% of all paper produced since 1850 is acidic. 50% of paper manufactured since 1850 contains lignin. The loss of endurance in this paper or specifically the fold endurance of this paper will drop by 82% in 21 years. From this can be calculated an average rate of 4.66%.

If books containing acidic mechanical wood pulp lose 82% of their original strength in the space of 21 years, then their further use is of high value from the point of view of preservation. Only through the most careful treatment can damage and material loss be avoided. Special instruction

should be provided for the use of these categories of the book-stock, so that the mechanical damage can be reduced to a minimum.

In 1986 a UNESCO/IFLA/ICA survey on the preservation and conservation of library and archival material was carried out on 300 archives and 550 libraries. The following report was compiled from the answers that were received:

- 66% of the establishments which were consulted stated that the climatic conditions in their buildings were regularly checked - only 45% analysed the results.
- 34% of all establishments have structural and climatic problems.
- 50% of the establishments stated that conditions had not changed in the last decade, 36% spoke of improvements and 11% of deterioration.
- In 88% of the establishments negative changes in the stock caused by usage were registered. The four main factors in question were frequent use, improper instructions for use, improper photocopying and the lack of facilities in the production of microfilm.
- About 60% of the establishments had a restoration work-shop at their disposal. Subsequent visits showed that the workshops did not correspond to their needs in the sense of space, personnel and technology.

The results of the UNESCO/IFLA/ICA survey showed some aspects of the state of preservation of cultural heritage on an international scale. It is evident that both the state of the stock in the libraries as well as the organisational and material conditions of preserving it through effective action must be very rapidly improved.

The situation of the libraries forces one to consider how the printed and written cultural heritage can be preserved. In the 70s' IFLA established a number of central programmes. In 1984 a special project group recommended the supplementing of the three groups already in existence (UAP, UBCIM, UDT) with further programmes, amongst them the new central programme for preservation and conservation (PAC).
The activities of this programme (PAC) are directed at the co-operation between IFLA and other organisations, the working out of strategies, studies and research projects, the training and further education of qualified employees as well as pilot projects. The international centre for PAC has its seat in the preservation office of the Library of Congress in Washington and is supported by regional centres in Sablé (Bibliothèque Nationale in France), Leipzig (Deutsche Bücherei, DDR) and Caracas (National Library, Venezuela).
The PAC programme was brought into being at the first International Conference on conservation and library stock (in Vienna, 7 - 10 April 1986), which was organized by the Conference of Directors of the National Library (CDNL) in co-operation with IFLA and UNESCO. More than 120 directors of National Libraries and specialists from all over the world took part in this conference which was followed by a seminar on questions about training in the field of conservation in library schools. This was also promoted by the UNESCO.
The PAC central programme began its work with important selected projects. The 45 projects and recommendations from the Vienna conference were published by the international centre and published in the IFLA publication series. The regional centres started off with the training of conservationists.

Furthermore, agreements were made on the publication of an information circular, the "Internal Preservation News" by the International Centre with the help of the regional centres. Various studies on the following subjects, also promoted by UNESCO are now being worked on:

- a study on the problem of mould in archives and libraries.
- a study on the problem of protection from disaster.
- a study on the problem of mass preservation techniques.
- a study on the problem of repelling insect attacks on library and archive stock.

Steps are being taken to establish a data bank which will collect information on the worldwide situation of conservation and restoration of library material. In the regional centres it is possible to borrow French, Spanish and German versions of slide shows on subjects such as "the treatment of books in general stocks" and "planning a conservation programme", which have been made by the Library of Congress. In this way, considerable work towards realising the PAC programme has been initiated so that the main aims:

- to make sure that published and unpublished library material of all sizes can be retained in a useable form for as long as possible.
- to encourage ways of solving the serious problem of the physical wear and tear of library materials.
- to encourage the working-out of national and international standards of production, conservation and treatment of library materials, which from now on will be achieved with the help of a unified plan.

A pre-condition for the achievement of each preservation strategy is a social conscience - that society is aware of the problems of libraries and archives. It is unrealistic

to believe that a library is able to preserve its contents on its own. A national preservation strategy in connection with international co-operation is seen as an indispensable way of successfully preserving the cultural heritage of mankind. The setting-up of a national programme is being worked on in many countries. Also in the GDR there are ideas to develop activities on a national scale to solve the problems which have to be faced in the field of conservation and restoration. A programme has been worked out for the development of mass-preservation methods in GDR libraries.

4. Methods of Conservation

The lifespan of library material may be prolonged many times over by an effective policy of conservation on the basis of suitable techniques and methods of conservation. The necessity of restoration is thus delayed or prevented.
A considerable amount of effort in conservation is spent on looking for ways to cheaply renovate large collections which are suffering from paper deterioration due to acidity.
Behind this problem is the fact that from about 1850 onwards paper with acid content was used for printing which, apart from some exceptions is still the case. At the moment, information is growing worldwide on the worrying state of library contents. The Library of Congress believes a quarter of its stock to be so badly endangered that it may soon be unusable.
The British Library in London fears the damage to be of a similarly high degree in the library. The French National Library in Paris reported of 800,000 books which were detrimentally affected. The academic libraries of this country have also been aware of this problem for a long time.
The amount of money necessary to renovate the library contents on this scale cannot be estimated at present because the development of specialized knowledged is not able to give a clear picture on effective methods. At the moment, various systems of deacidification on library stocks are being developed or are already in use.
By the term "deacidification" we mean the removal or neutralisation of acid substances which have a damaging effect on the paper. The impregnation of an alkaline buffer is necessary to maintain the effect of deacidification for as long as possible. This buffer or reserve should act as protection against the secondary build-up of acidic substances or their

penetration from outside.
The work of William James Barrow is of central importance when researching the lifespan of paper. The most important findings for us from his, in parts, contraversial research results may be thus summarized: The lifespan of paper is determined by the presence or absence of alkaline earths. If there are enough alkalines in the paper, damage done by acid can be prevented. If there are too few alkaline earths in relation to the amount of acids or if there are more acids then can be combined then the pH value will fall.
From the many types of alkaline substances, there are few which are suitable for the deacidification of paper. Particularly strong alkalines are unsuitable because a vigorous reaction to the cellulose causes a similar tendency towards ageing. The most valuable deacidifying agents are the alkaline earth salts
calcium carbonate ($CaCO_3$),
magnesium carbonate ($MgCO_3$) and
barium hydroxide ($Ba(OH)_2$).
In mass-deacidification the paper should be neutralized to a pH level of 7 - 8 by the treatment. Technically, this means that books or bundles of paper have to be rapidly impregnated with a neutralizing agent, which is deposited in a sufficient concentration in the paper-web, at the same time building up the alkaline reserve. The chemicals used must not damage the books. They must be non-toxic and must not leave any kind of odour. The techniques of mass-preservation which have been developed up to now are gas or fluid processes. Some of the latest use both aqueous and non-aqueous systems.
Deacidification is purely a preventive measure. It does not return any of the paper's strength which is also essential so that the book can be used and the pages can be turned, and the strength which is lost as a result of the chemical pro-

cesses, making as a whole a difference to its ageing. The deacidification simply has the effect that these processes are in future slowed down as much as possible.

4.1. The Diethylzinc (DEZ) method

After an exhaustive research programme lasting five years, the Library of Congress decided for the gas phase method, where a substance called diethylzinc (or DEZ for short) is used. This method has been demonstrated on a laboratory basis on test models.
DEZ cannot be directly exposed to an excess of water or oxygen because of its reactive characteristics. Therefore the process has to be carried out in an enclosed chamber, so that the books and the DEZ gas can react in one enclosed space which is free from excess water and oxygen. Diethylzinc is a compound with characteristics which raise its deacidification mechanism above others.
Firstly, the DEZ vapours in the form of gas can flow between the pages of the book unhindered, disperses itself in the paper fibres, coming into close molecular contact with the cellulose chains and reacting with and neutralizing all weak and strong acids.
Secondly, it simultaneously reacts with the water on the fibres and forms the alkaline reserve compound zinc oxide. This reaction between the DEZ molecules and the water leads to an even distribution of small alkaline reserve particles in the paper fibres which means a completely reproducible increase in the lifespan of each book treated.
Thirdly, the zinc oxide buffer gives the paper fungistatic activity which prevents any later biological growths.
The DEZ process consists of 3 stages with altogether 17 single steps. The schematic sequence consists of the

following:-

The treatment chamber is filled with books. All the air is pumped out to ensure the total absence of air, producing a pure nitrogen atmosphere. A vacuum of approximately 0.2 torr is then created in the chamber at a temperature of 45°C to draw out the greater part of the water content in the books. Approximately 0.5% water must remain in the paper. The water content of the paper is checked by measuring the weight loss of the vacuum chamber when full of books. This preliminary stage of treatment takes 20 hours.

The DEZ is condensed out of its transport medium (mineral oil) from a closed system linked with the vacuum chamber, and in the form of a gas, is dispersed slowly amongst the books in the vacuum chamber. The pressure inside the chamber thus increases to 20 torr. The DEZ gas reacts with the 0.5% water which produces zinc oxide and ethane. This process is intensively exothermic. The ethane which is produced is constantly drawn off. At the same time the vacuum chamber is cooled so that a temperature of 80°C can be maintained. The conversion of DEZ into zinc salts and zinc oxide takes about 4 hours and the weight check of the vacuum chamber may then be carried out.

The safe removal of the unused DEZ gas is achieved by re-creating the conditions of the pre-treatment stage in the vacuum chamber: 0.2 torr, a nitrogen atmosphere, 40°C. Under these conditions water is let into the chamber to increase the water content of the books again. Afterwards carbon dioxide is pumped into the chamber raising the inner pressure to 550 torr. It is assumed after 24 hours that most of the zinc oxide has been converted into carbonate

and that the books have absorbed so much water that they are again flexible enough to handle.
The advantages of the DEZ process are as follows:
- The use of a substance in gas form generally means that many of the acutely damaging side-effects on parts of the book can be avoided.
- The alkaline reserve which is created reacts almost neutrally.
- The selection of library materials is not necessary prior to treatment.

From the present point of view the disadvantages are as follows:
- The construction and maintenance costs of a DEZ deacdification plant is very expensive.
- There are some elements of uncertainty because of the unstable reactive nature of the DEZ gas.
- Specialists are required to run this kind of plant.
- The whole chemistry of the process is, at present, being questioned by experts.
- The present stage of development of the process does not permit its use by potential customers.

4.2. The Wei T'o method

The Wei T'o **non-aqueous book deacidification system, or simply** the Wei T'o system, invented by Richard D. Smith in Canada, and developed by the National Archive in Canada. Work on the test plant started in 1974 and ended in 1978. After completion, meticulous tests on books from the Canadian Book Exchange Centre of the NLC began. By December 1981, the system was ready for practical use. It works as follows:
The books to be deacidified are soaked in a mixture of freezing substances (frigen, FCKW's) as a transport medium and a deacidification agent methoxy magnesium methyl carbonate

dissolved in 5% methanol.
As a result, the acids in the paper are neutralized through the formation of magnesium sulphate and the depositing of magnesium carbonate as a buffer with a pH value of between 7 and 8. The Wei T'o spray Nr. 10 consists more or less of this combination, its ue being widespread in the deacidification of single sheets.
The books which have been sorted out for the mass deacidification are dried in wire baskets for 36 hours in a vacuum dryer. In this way, the paper's natural water content is removed. Two baskets which contain between 20 and 30 books are then placed in the reaction chamber. The deacidification solution is then pumped in and the pressure increased so that the books are fully saturated with the solution. The solvent is then removed (to be used again later) through a second drying process. At the end of the treatment warm air is pumped in, normal air pressure is restored and the books are then taken out.
The deacidification cycle recuires approximately one hour. The baskets are placed in simple conatainers with corrugated bottoms where the books can cool off to room temperature and regain their normal water content through the air. They are then checked and taken back to their respective departments.
The plant in the cellar of the Canadian National Library is actually only a test plant. It has been in constant use since 1982. The output of the plant depends on the amount of capital and personnel available.
At the moment around 800 books can be treated by the two employees during their 37 1/2 hour working week - that is about 40,000 books every year. The output is to be doubled:

80,000 books is the amount of books coming into the Canadian library and it is planned to deacidify them as a completely preventative measure. The maximum output in a 12-hour shift system shared between 7 employees would amount to around a million books a year. A further development to the plant, such as a multiple single-chamber system would cut out the re-loading from the vacuum-dryer chamber to the intermediate chamber and finally to the treatment chamber, which is at present the case, and would therefore reduce the amount of employees at this level of output.

The technical advantages of the Wei T'o system lie in its chemical agents:

- The metallo-organic compound magnesium methylate is soluble in methyl alcohol.
- If this solution is introduced to paper it decomposes, simultaneously forming magnesium hydroxide and magnesium carbonate as well as methyl alcohol which evaporates very quickly.
- Magnesium hydroxide and magnesium carbonate remain in the paper, form an alkaline reserve and delay the process of oxidation.
- There are no reservations as far as the chemicals are concerned.

The disadvantages lie, at present, in the following problems:

- Due to the fairly good experience in its use, further developments to optimize the process would be possible. Improvements in the procedure were announced already some time ago by the inventor, although not yet put in concrete terms.
- The solvents used or produced in the process are not

ecologically feasible (cooling substances) and are toxic (methyl alcohol).

- A great disadvantage of the present plant is the full recovery of the solvent.
- The library materials to be deacidified must be pre-selected.
- The amount of methanol in the deacidification solution can lead to unwanted changes in specific materials.
- A serious drawback is the potential customer's dependence on the manufacturing monopoly of the deacidification solution.

4.3. The deacidification system of the Bibliothèque Nationale

Out of all European countries, efforts to find a preventive mass deacidification system are the furthest advanced in France. The National Library installed a conservation centre in the Château de Sablé, 250 km south-west of Paris, which was put into use in mid 1987.
The procedure is similar to that of the Canadian Wei T'o system. The books are neutralized with methyl magnesium carbonate in a solution of methanol and cooling agents.
As opposed to the Canadian system, the system in Sablé is geared towards the distillatory processing of the used solution so it may be employed again. The way of working is roughly the same as in Ottowa. The money invested in the plant amounted to 2 million French francs. The books are dried in a vacuum at 50°C for 24 hours, then taken to a cooling chamber and intermediate chamber for 48 hours and then with 1% humidity for 10 minutes in an evacuated pressure chamber which is saturated with the deacidification solution. Afterwards the surplus deacidification solution is pumped out of the pressure chamber and the saturated books are heated to remove the methanol. The pressure chamber can be filled three times a day with 200 books. Exact figures on the output of the plant are expected.
The advantages fo the French system are exactly the same as those of the Wei T'o process in its chemical activity of neutralization and impregnation of alkaline reserve. Another advantage is the effort made to win back the expensive solvent.
The disadvantages of the French system are currently as follows:

- The whole plant can only be seen as an experimental plant.
- A number of technical changes aimed at replacing the present manual control with partly automatic operation must be achieved.
- There are problems with ink running in books which could be solved by reducing the amount of methanol.
- Efforts to find a supplier of the deacidification solution in the surrounding area of the plant have proved unsuccessful.

4.4. The methods of the British Library in London

The library commissioned the research of possible alternative processes to treat paper which would delay decomposition and strengthen the paper for further future use. This could be achieved by the absorption of polymers into the substratum, thus strengthening and protecting each individual paper fibre. Present laboratory results show that the treatment must include the following steps:

- The books to be treated have to be stacked in a suitable container.
- Nitrogen is pumped into the container in order to remove air and free oxygen.
- a quantity of monomer compound which corresponds to the weight of the books is introduced into the container.
- The set-up has to rest some hours so that the monomer compound can diffuse and distribute itself evenly throughout the paper.
- The monomers and the books are passed through a weak gamma ray source until the correct amount of radiation is achieved. The monomers are thus converted into polymers and are simultaneously chemically attached to the paper or substratum forming a polymer compound.

- The monomer residue is removed with air from the container to avoid endangering the employees involved.
- The books are then taken out of the container and stored for a few days in a well-aired environment to make sure that all traces of monomers have disappeared before the books are returned for sorting and shelving.

Furthermore, it was found that it is possible to also use a basic co-monomer (an amine-substituted acrylic methacrylate as for example dimethylaminoethyl methacrylate) to neutralize any acids in the paper and so that resistance is increased to later acid attack, thus combining neutralization and strengthening in one step. The basic co-monomer is simple to polymerize and only small amounts are needed for the neutralization to function.

Test pieces which have been treated with the usual polymer compound and with the small amounts of **polymerized amine show** noticeable differences in paper strength and in its neutrality over a certain period of time. Recently it was discovered that multiple unsaturated co-monomers with the monomer compound added to them could cause an even greater improvement in the fold endurance, 3 - 5 times more than that of the original polymer compound, increasing life expectancy.

The expected results of this process is the combination of deacidification and, at the same time, stabilisation. The present stage of development does not permit the use of the process by any potential customers.

The"Viennese method"

The procedure for preservation of newsprint developed at the Austrian National Library is based on an aqueous immersion treatment. The treatment involves the simultaneous neutralization and re-strengthening of the paper. The method allows the renovation of embrittled paper in the sense of prolonging

its further library use, but also the preventive treatment of undamaged stock. As with the DEZ process and the methyl magnesium carbonate process, a vacuum chamber is required for the immersion of the paper in neutralizing and strengthening solution. The simultaneous neutralization and re-strengthening has the advantage that, besides causing considerable deacidification and the formation of an alkaline reserve in the paper, an additional strengthening solution is introduced, retarding further decomposition of the paper, due to the influence of oxidising agents. On the basis of previous test experiments, calcium hydroxide was selected as a deacidification solution and a methyl cellulose of low viscosity was chosen as a strengthening agent. After impregnation, the items are shock frozen at a temperature of -40°C and then freeze-dried. The freeze-drying prevents the individual sheets from sticking together during the drying process. The process is basically designed for the treatment of complete book-blocks after the removal of the book's cover. The ability of the immersive solution to penetrate through the book-block is decisive for the success of the treatment. A closed book acts like a selectively absorbing filter towards the immersive solution, comparable to the absorbing layers of a thin-layer chromatography plate. This means in practice that the solvent - in this case water - penetrates through the material more easily than the dissolved chemicals which should bring about a neutralization and strengthening of the paper. This problem can be overcome technically by limiting the thickness of the spine to a maximum of 4cm. Thicker books can be treated by splitting the bindings and dividing

the book blocks so that the resulting spine thickness of the individual blocks does not exceed 4cm. The oversewing of the book-block remains to prevent the individual pages from moving during treatment.
A further improvement of the solution's ability to penetrate can be achieved by using a re-strengthening agent of very low viscosity - with the solution of MC 40. Although the strengthening effect of MC 40 is weaker than products of higher viscosity, as for example MC 400, the paper fibres are evenly coated and according to present experience and tests, sufficient strengthening of the treated paper is achieved.
The advantage of the Viennese process is the combination of deacidification and strengthening of the bound sheets. The idea of the process and its implementation is the result of many years of experience in restoration. The Viennese method can be adopted by those who are interested.
The disadvantage of the method lies,at present, in the restricted output, which depends on the size of the plant.

4.6. Further developments

Besides the deacidification systems described above, which require considerable investment due to their dimensions and comprehensive technical plants, deacidification and strengthening processes which involve little effort are becoming more known.
A recent development is that an English firm "Archival Aids" in Spondon, Derby, has been able to offer a "paper treatment spray" and the "Archival Aids HCMC solution" to deacidify and strengthen paper. The deacidification solution is based on methyl magnesium carbonate. HCMC is a non-aqueous, colourless, alkaline cellulose solution which can be applied either by spraying, dipping or painting or with the help of "Archival Aids" spraying equipment.

At present the solutions contain, apart from methyl alcohol : also trichlor-triflour-ethane. The spraying equipment offered by the firm permits the treatment of individual sheets and bound books in a manual way.
The Interleaf VPD process of W.H. Langwell consists of a gaseous phase deacidification process. Cyclohexylamine carbonate chrystals are impregnated into the paper or sealed in porous packets. The impreganted sheet is interleaved in books or the sealed chrystal bags are placed inside boxes containing the documents. In the successive days the chrystals volatize, producing cyclohexylamine gas which deacidifies.
The treatment is not permanent. Cyclohexylamine is a toxic substance.

The book-keeper process of J. Kozak and Richard E. Spatz is based on the application of a non-aqueous suspension, impregnating the books with magnesium oxide and freon. The impregnation process is optimized by agitating the books in the suspension. The whole process takes 3 hours. The freon is evaporated and recovered in a vacuum during the renovation phase. At the moment, tests are being carried out with the help of a pilot container in a pilot project.

The parylene gas phase consolidation, a joint project between the American Institute and the library of the Science Academy in Leningrad aims to strengthen paper using polymers in the form of a gas (diparaxylylene). At the present stage of development, paper can be strengthened through the mechanical combination of parylene and cellulose. The process is irreversible.

5. Methods of restoration

The equipment used in restoration has undergone various changes in the last decade.
It is marked by the growth in knowledge through research into basic scientific principles and their being put into practice.
Efforts to structure conservational processes in a more efficient way has led to the results which will be outlined in the following but which are in no way complete.
It is quite evident that the results are the most impressive when it is in the form of international co-operation and exchange of information. The trend of using conservational methods, bringing quality and quantity into unison, is continuing.
The technical basics which the restorer has at his/her disposal are now more comprehensive and greatly improved. At the same time one cannot overlook the fact that exaggerated commercialization and the range of conservational techniques and equipment have restricted the distribution of efficient methods.

5.1. The wet treatment

Wet treatment (which consists of a succession of cleansing, deacidification and buffering immersions and basic conservation) is particularly a big problem for extensively,badly damaged books because of the great amount of time and energy involved. Moreover, wet treatment is decisive for the quality and lifespan of the treated books and sheets.
The traditional manual wet treatment of paper suffers from some methodical shortcomings. Only in the rarest of cases can, for example, a large amount of single sheets be treated under absolutely the same conditions. The amount of time needed for laying the sheets in and transporting them through the basins inevitably creates differences in the time the solutions need to take effect on single sheets or groups of sheets.
Thorough rinsing and checks on the procedure are measures which are not often taken in practice.

Deacidification and the creation of an alkaline reserve generally occurs empirically without general checks and exact stipulations on the measurement of the solutions. The often brittle state of the paper makes the handling of it more difficult and means that special safety precautions are necessary, which increases the work involved. The danger that the restorer is exposed to, being in contact for often hours with the fluids and chemicals is a further problem under the circumstances which can only be reduced somewhat by protective clothing. All qualitative disadvantages of the manual wet treatment can be eliminated through a great deal of work with technical appliances in the workshops, but the quantitative results cannot be improved upon because of the limits of human capacity.

Mechanical wet treatment solves qualitative and quantitative problems and reduces the overall work in wet treatment. The plant at the Deutsche Bücherei in Leipzig consists of six basins arranged alongside each other, measuring 50 x 70 cm and 60cm deep. A transportation device, which allows for the horizontal or vertical transportation of the sheets is situated above the basins. The basins are made of steel with a coating of vulcanized hard rubber. Every basin is provided with heating, ventilation, a thermostat and are fully plumbed in with overflow. The whole plant is linked up to the central hot and cold water and compressed air systems. The compressed air pipe directly in front of the plant allows the introduction of CO_2 gas. There is a control unit every three basins. Every basin has a pH value guage. The readings can be taken from an electrode switch

on a measuring instrument.
These technical pre-requisites guarentee exact and verifiable wet treatment according to individual requirements.
At the moment the following programme can be carried out on the plant on the basis of tested procedure:

1. Water basins of varying temperatures (between 20 and 100°C)
2. Oxydation bleaching using potassium permanganate
3. Neutralization and use of an alkaline reserve using alternatively sodium tetraborate, magnesium or calcium hydrogen carbonate
4. Oxidation bleaching using hydrogen peroxide
5. Reduction of lignin in paper made from wood pulp using peroxide carbonates and potassium permanganates
6. Solution of glues, chiefly with starch and protein glues with the help of enzymes. As a kind of side-effect, the removal of the supporting sheets after the paper splitting process can be carried out in an optimum way
7. Basic conservation of all sheets of paper using p-hydroxdiphenyl methane.
8. Re-sizing of the treated sheets with cellulose ethers or protein solutions.

The given examples can be varied and combined so that specific and effective wet treatment is possible - according to the kind of damage to be treated - making everything much more economic. The use of chemicals, the amount of water and energy consumed and not least the problem of waste water have definite advantages over the manual procedure.
If one considers all the necessary steps in the process from the dismantling of the book to the start of the stabilization process as a complex, then a thought-out organization of work

saves considerable amounts of time. The fact that the dismantling and dry-cleaning can be coupled with the formation and ordering of different groups of damaged books permits, apart from a sophisticated way of working with the wet treatment plant, a positive influence on the hygienic and micro-biological environment in the workshop.
The pages to be treated are arranged in special sieve rolls after dry-cleaning and independent of the degree of damage. The sieve rolls consist of a wooden structure (comparable to the wooden spool of a cotton reel) and two polymide sieves, one lying on top of the other. The sieve lengths are eight metres long and 40cm wide. The course-meshed sieve is needed to keep the sheets of paper apart and is simultaneously the transportation sphere for the different fluids. The second, very fine-meshed sieve lies on top of the first course-meshed sieve.
The sheets to be treated are placed on the course-meshed sieve and are covered with the fine-meshed sieve. The spool is then inserted on a simple winding device, and after the sheets are in position, the sieve lengths are rolled onto the spool. Varying amounts, on average 50 sheets (depending on format), can be accommodated in the sieve roll (which measures 40cm wide and 16cm in radius. Two catches secure the sieve rolls which are then removed from the winding device. After fitting a new spool, the next sieve roll can be wound on. In these sieve rolls the individual sheets cannot slip around but remain perfectly secure so the different substances during the various stages of treatment can penetrate the sieves and reach every point of the sheets. In the whole duration of the wet treatment the paper sheets

do not suffer any mechanical damage. The sieves guarentee rapid penetration and draining of the fluids and can withstand constant use over a longer period of time. Eight of these circular sieves (about 400 sheets) are placed next to each other in simple sheet containers. Once the wet treatment is over, the wet sieve rolls are opened and hung up in a simple drying frame. The rest of the drying process is achieved in a short time by laying the sheets flat and allowing them to dry at room temperature.

A system of wet treatment has been developed at the University Library of Jena which starts treatment with dry, disintegrating books and finishes with chemically cleansed, disinfected and deacidified paper with a reduced amount of lignin. With this kind of wet treatment it is guarenteed that every individual sheet is fully rinsed because of the even adhesive effect on both sides of the paper so it is therefore not subject to any mechanical strain and is carefully dried in warm air.

The cassettes for the wet treatment, which were based on a modular construction system, allow a daily productivity of 1,260 sheets (large folio) or 2,520 sheets (folio). One cassette contains 70 polyester sieve bags which can accommodate the deteriorated printed matter. A 150-litre steam-boiler can supply three cassettes. When the wet treatment has come to an end, the cassettes are extended to a length of 150cm by fixed pieces of dowelling. Four extended cassettes can be dried on trolleys with shelves.

The advantages of the cassettes for the wet treatment are:

- maintenance-free use, high efficiency
- saving of additional hardboard, filter cardboard and filter paper for drying
- reduction in the amount of spores of micro-organisms which attack paper in the workshop

- the conditions necessary for lignin reduction and enzymatic wet treatment (even rise in temperature during the treatment are guarenteed.

In conventional wet treatment, decaying stock is treated between supporting sheets and sieves. Due to this fact, it is subject to uneven rinsing and harmful currents. The adhesive action on both sides of the paper between support papers and the original material does not exist. The horizontal method of treatment is possible on single sheets and stable paper.

Lignin reduction in wood pulp paper or the systematic removal of the gelatine coating of split paper would, within the programme of mass treatment, with conventional horizontal wet treatment lead to uncontrollable damage to the materials. There are years of practical experience behind the procedures and aids described above. Both protective systems mentioned above in the form of sieve rolls and sieve bags complement each other and fully cover the needs of wet treatment.

5.2. The possibilities of the leafcasting technique

Putting the composition of the fibres aside, paper's strength comes from the felting of fibres against each other, from the adhesion between the fibres and the formation of bonds between them without any glueing process being involved.

The procedures of making normal paper form the theory behind the principle of leafcasting.

The damaged sheet is laid on a piece of permeable material which is comparable to a paper-mould used by a paper-maker. The pulp, which is greatly thinned down, comes onto the piece of paper and is sucked downwards through the sieve. The piece of paper on the sieve creates a barrier for the stream of pulp so that the single paper-fibres can only

settle on areas of the sieve where there is no obstacle to the stream of pulp. The missing parts of the page and all exposed parts of the sieve become covered with matted fibres, that is, new paper. The way this principle functions is influenced by different factors - the kind of sieve, the state of the fibres, the strength of the vacuum etc.

The leafcasting method is an internationally widespread way of filling missing parts of paper, and can be seen as an important development in recent years. In the seventies leafcasting devices were constructed on the basis of simple manual processes, which filled holes in paper with the help of paper fibre suspensions.

These devices can treat a number of sheets in one step depending on the size of the work surface. The Leningrad leafcasting device is the most efficient device of its kind because here the peripheral work, such as the preparation of the fibres and the further treatment of the restored sheets of paper to the book-binding stages, is all integrated.

Leafcasting, as a kind of stabilizing technique, can, particularly in the case of mechanical damage, produce excellent results, which are also acceptable from the economic point of view. The need to mechanize restorative work processes, to overcome the problem of mass restoration, led to the development of the Copenhagen device. Per Laursen and Lars Grønegaard[8] developed a leafcasting device which facilitates the leafcasting process to function non-stop. The four-metre long machine consists of a frame for the moving paper sieve and the leafcasting unit. The damaged sheets are placed on the sieve, pass through the leafcasting unit and can be taken off the sieve, fully restored, at the other

end of the machine. The relation between the concentration of the fibre pulp and the speed of the"sieve conveyor belt" is decisive for the leafcasting process. The time-consuming factor of having to ascertain the amount of fibres necessary for every damaged sheet of paper becomes superfluous with the Copenhagen device. A photoelectric cell in the pulp basin guarantees that the concentration of fibre material stays constant but may be regulated. The passing of the damaged sheets through the leafcasting device depends on the speed of the sieve conveyor belt and the format of the sheets, but should take between four and ten seconds.
The expert can easily see that in this way the leafcasting process may be made more rationalized, taking into account the importance of mass restoration.
The restorer John F. Mowery of the Folger Shakespeare Library in Washington has developed a highly precise system for particularly difficult leafcasting work, such as the restoration of paintings. A manual leafcasting device is linked up to a video camera. The camera detects the missing parts in the original and transfers the results to a computer so that the necessary amount of fibre is determined quickly and exactly.

5.3. The possibilities of the paper-splitting process

Interest in paper-splitting as a method of restoration for decaying books has rapidly grown in recent years. Nearly every restorer is well-informed on the principle of paper-splitting. Technology is diverse and the results in restoration differ. Paper-splitting is the most demanding technique for the restorer. It is linked with complicated operative work on the inner substance of the paper. Only

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through years of training, a great deal of concentration on the work and care can guarentee that every piece of material threatened with decay can be restored to its original state. This kind of specialized technology may be mastered by restorers with many years of practical experience.

Otto Wächter referred to possibilities of neutralizing and generally stabilizing decaying material and that the paper-splitting process which has been further developed in the GDR is "... at the moment the most sound restoration process for rotten, decaying paper which has been eaten away by ink ...".

This remark refers to the true-to-the-original restoration of irreplaceable rarities and to mass restoration of other materials.

The paper-splitting technology which has been developed in the GDR is the result of many years of work done by restorers of the Deutsche Bücherei and the University Library of Jena. The present level of work and the technological forerun are thanks only to the two establishments. The reason for this success is not so much due to the splitting process itself, which takes a matter of seconds, but much more to the whole field associated with restoration. The considerable reserves of increased capacity can be attributed to the preparative and evaluative work, to the technological specialization and the willing application of the leading restorers.

Here are the following basic principles for the paper-splitting process developed in the GDR:

- Paper-splitting, as a part of general restoration, guarentees true-to-the-original maintenance of print, inks, colours, and structure of the paper fibres. The increase in the

paper thickness by general inner stabilization is not as great as with other methods of restoration (lamination with Japanese paper, chiffoning or lamination in synthetic materials).

Paper-splitting must be reversible for future generations without causing them too great a loss of material or too much inconvenience materially or technically. Priorities aimed at include the use of materials which are resistant to ageing.

Taking into consideration the present level of knowledge in the field of paper-splitting, any reserves in capacity which have still not been fully exploited may be developed, even in restoration workshops of different kinds. For reasons of efficiency and quality, perfect paper-splitting concentrates on three independent kinds of device which are nevertheless organically bound to one another.

The sophisticated equipment used in the wet treatment, in leafcasting and in paper-splitting is very expensive. This means that smaller and middle-sized workshops are often overstretched from the point of view of staff, space and money. With the greater employment of machines in the field of paper-splitting, the realistic aspects of business management such as the cost/profit ratio have to be increasingly taken into consideration.

Recent research has shown that paper in danger of decay, of varying thicknesses, with holes and different formats lends itself perfectly to the paper-splitting process using the adaptable and non-adaptable method. The subsequent paper-splitting and general stabilization is characterized by great savings in material, working hours and continuous

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step-by-step production with the sheets of paper which have been treated in the leafcasting process.
The development of a paper-splitting machine in the Deutsche Bücherei, Leipzig,has been successfully and constructively concluded. Efforts to find a partner for the construction of the plant in Leipzig are fully underway. The first batch of special materials for the construction have already arrived in Leipzig. At present preparatory work is going on to match up the Per Laurson leafcasting device to the paper-splitting machine.

5.4. The lamination process - alternatives

The use of lamination as a way of stabilizing library and archive materials can be seen as a contraversial process of preservation. On the one hand it is classified as "ultimo ratio" and on the other hand as an acceptable method of preservation. Putting all the different attitudes aside, the lamination of paper with different kinds of synthetic materials is internationally a widespread practice. Generally, the surfaces of the paper are covered with a layer of foil, that is,the foil covers the original with a homogenous layer, of which only a small part is melted to the surface of the paper. Furthermore, it is also possible to impregnate the original with foil. In this case, the melted thermoplast penetrates the whole fibre structure of the paper and is hardly noticeable on the surface of the paper. This kind of stabilization requires the paper to be quite stiff and thick, since otherwise the paper loses its opaqueness and takes on an unpleasant transparant quality.The third possibility consists of using the lamination foil as a melting adhesive, if for example, materials sensitive to water are laminated with a foil interleaf

together with a new backing material. The effects of lamination, impregnation or coating always depend on certain conditions such as pressure, temperature, time, the thickness of the foil and the state of the original.
The originals which are to be laminated should undergo a preparatory phase. This preparatory phase has a significant influence on the durability of the laminate. Firstly, as part of the usual wet treatment, everything is done to delay the natural ageing process of the paper (cleansing, neutralizing, alkaline reserve etc.). The inner causes of paper-ageing are of primary importance in the laminate because the exterior causes are to a great extent ruled out through the lamination process. Furthermore, the lamination process is irreversible, so that although de-lamination is possible, access to the original is no longer possible. Although it is possible to separate different types of foil from the original, using organic solvents which may be successful in some exceptional cases, this cannot be said for the majority of laminates. It is reasonable to expect that the precautions taken according to the present level of knowledge when using the lamination method is a necessity of conservation. The optical phenotype of laminates is, to a large extent, determined by the foil and the isolation material used in the treatment. The isolation materials prevent the surfaces of the laminate from sticking to the heated plate of the laminator. Depending on the surface structure of the isolating materials, the laminate surface can appear smooth, shiny or hardly perceptible. If a thin sheet of Japanese paper is laminated onto the surface together with the foil, the durability is improved

and the surface of the foil takes on a matt appearance. The depth of the structure is important for the finish of the laminate surfaces when using textured release sheets. They should not be more than 1/4 of the thickness of the foil, because otherwise the laminate surfaces will be too thick and the remaining surface thickness of the foil over the original will be partially too thin.
Obviously in previous years there has been a growing trend to replace lamination as a way of stabilizing paper with other alternative methods. These alternative methods should be of a more conservational nature whereby paper is protected, strengthened and its use is prolonged, but also so that the original is not irreversibly fused to the foil. The process of encapsulation, developed by the Library of Congress, is able to do this. The original is placed between two sheets of polyester film which is sealed on all four sides. In this way it is protected, strengthened and still usable. If necessary, the original can still quite easily be removed from the "envelope". Similar methods can also be put into practice - for example with industrially manufactured envelopes made from polythene foil. With these kinds of materials a slight electrostatic charge is built up between the original and the material of the envelope, which prevents the paper from slipping around.
It is quite obvious that these kinds of methods, when well-organized, are much more efficient than normal lamination processes.

6. Conclusive Remarks

The most important results of recent years in the field of books and paper restoration are:

- The vertical position of the sheets during wet treatment,
- Periphery solutions used in paper-splitting and leafcasting,
- The ability to maintain aesthetic works which are badly damaged.

The introduction of safety measures such as the use of polyethylene and polyester sieves with the vertical positioning **during all wet treatment has proved itself to be the best way** of working. This factor will seriously affect the work organization and the basic equipment of the restoration workshop.

Apart from the absolutely safe handling of even very fragile items, here also can quantitative and qualitative results be achieved, which are far above the results achieved with the orthodox methods. The high costs of investment at the outset pay off very quickly, and the fact that the lifespan is increased and that handling and care is simplified, guarentees a longer period of usage.

Paper-splitting and leafcasting with the "long-sieve" machine (invented by Per Laursen) are well-known methods of stabilization which are capable of treating several hundred pages a day. It soon becomes evident that paper-splitting and leafcasting, as integral parts of stabilization could be put into practice very quickly. The main problems and reservations in both processes are to be found in the preparatory and follow-up processes of paper treatment. The use of sieves and felt made from synthetic materials and polypropylene felt means that work is made more efficient. The combination of leafcasting and paper-splitting opens up further possibilities in high-quality restoration work.

So that literature can be maintained in its original form, all proof of historical sources should be kept. This includes the surface structure of the paper, sand-imprints of inks and other water-soluble printing materials.
According to new discoveries it is questionable whether deteriorating inks, in differing stages of decay, should be exposed to the wet treatment. Some kinds of iron gall inks and iron sulphate inks in literature decay in a similar way to rust. Wet treatment causes uncontrollable deletion or bleeding of inks and colours as well as the distribution of loose particles of the surface of the paper.
Any known risks and elements of uncertainty can be reduced when treating paper with decaying ink by the proven technology of paper-splitting. Discolouring in coloured illustrations or on historical maps etc. is one of the most serious kinds of damage in paper. Partial splitting of large format paper in particular opens up new horizons in restoration. The splitting process and the subsequent stabilization through the insertion of new material is only carried out on restricted areas of damage, whilst other areas of the paper which are still intact remain in their original state.

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